European Polymer Journal 85 (2016) 499–507

Contents lists available at ScienceDirect

European Polymer Journal

journal homepage: www.elsevier.com/locate/europolj

# Tailoring soy protein film properties by selecting casting or compression as processing methods

Tania Garrido [a], Itsaso Leceta [b], Sara Cabezudo [c], Pedro Guerrero [a], Koro de la Caba [a,*]

[a] BIOMAT Research Group, University of the Basque Country (UPV/EHU), Department of Chemical and Environmental Engineering, Engineering College of Gipuzkoa, Plaza de Europa 1, 20018 Donostia-San Sebastián, Spain
[b] BIOMAT Research Group, University of the Basque Country (UPV/EHU), Department of Applied Mathematics, Engineering College of Gipuzkoa, Plaza de Europa 1, 20018 Donostia-San Sebastián, Spain
[c] BIOMAT Research Group, University of the Basque Country (UPV/EHU), Department of Business Management, Engineering College of Gipuzkoa, Plaza de Europa 1, 20018 Donostia-San Sebastián, Spain

ARTICLE INFO

*Article history:*
Received 30 August 2016
Received in revised form 2 November 2016
Accepted 4 November 2016
Available online 5 November 2016

*Keywords:*
Natural polymer
Manufacture
Functional properties
Film structure
Sustainability

ABSTRACT

This work describes how the manufacturing process selected to prepare soy protein films can affect both material properties and environmental impacts. Casting (wet process) and compression (dry process) were the processing methods employed, giving rise to films with different properties. In particular, the changes observed in thermal, optical, barrier and mechanical properties were related to the changes in the film structure and to the intermolecular forces involved during the film formation. On the one hand, casting films presented a higher hydrophobicity and water resistance and a lower yellowish colour. On the other hand, compression films were more transparent and had a smoother surface due to a higher degree of protein denaturation. Moreover, compression moulding allows less time-consuming manufacturing, which can be considered a benefit for industrial applications, but also for sustainability concerns. With this regard, life cycle assessment (LCA) was carried out in order to compare the two processing methods employed in this study due to the fact that the environmental aspects are an essential criterion for decision making when selecting materials and manufacturing processes.



## 1. Introduction

Petroleum-derived plastics have widespread use nowadays, but they are not renewable and most of them are non-biodegradable, causing environmental problems. These environmental concerns have led to an increasing interest in developing biodegradable materials derived from renewable resources [1,2]. Biopolymers derived from residual biomass are regarded as an attractive alternative as they are abundant, inexpensive, renewable, and biodegradable. In particular, soy protein isolate (SPI), obtained as a by-product in the soy oil industry, has functional properties suitable for the development of biodegradable films. Soybeans represent one of the largest sources of vegetable oil [3], providing an abundant, available and renewable raw material. Typical soybean composition is 20% oil, 40% protein, 35% carbohydrate and 5% ash (on a dry weight basis) [4,5]. Conventionally, oil from soybeans has been extracted using hexane as solvent [6]. However, enzyme-assisted aqueous extraction has recently been proposed as an environmentally friendlier method [7]. Furthermore,

* Corresponding author.
*E-mail address:* koro.delacaba@ehu.eus (K. de la Caba).

http://dx.doi.org/10.1016/j.eurpolymj.2016.11.007
0014-3057/

oil yields greater than 95% have been achieved with this alternative method and both oil and protein can be obtained simultaneously in the same extraction process [8].

The structure of protein-based films depends on the amino acid composition, the degree of protein denaturation, the type of interactions among protein chains, and processing methods used, which determine their final properties [9,10]. Wet and dry processes are the methods employed to prepare films. The wet process or solution casting is the most commonly used method to develop protein-based films at laboratory scale [11–13]. However, compression moulding is particularly suitable for larger scale production due to its simplicity and shorter time consumption [14,15]. Owing to the fact that the glass transition temperature of proteins are generally very close to their thermal degradation temperatures, compression has not been widely used for proteins, limiting their commercial application [16]. However, the use of plasticizers may overtake this problem and widen the range of processing temperatures. In general, plasticizers with small molecular weight can be easily incorporated into the protein chains, exhibiting an efficient plasticizing effect. Water is an effective plasticizer, but it evaporates when processing temperature is higher than 100 °C, and the film becomes brittle; therefore, a less volatile plasticizer, such as glycerol, can be a more suitable compound. Furthermore, glycerol can interact by hydrogen bonding with protein at amine, amide, carboxyl and hydroxyl sites, decreasing inter- and intra-molecular interactions among protein chains, improving their motion ability and resulting in flexible films [17]. In a previous work [18], thermal and mechanical properties of soy protein films prepared with different glycerol contents (30–50 wt% glycerol) were assessed as a function of the processing method employed. For that, SPI/glycerol dispersions were prepared to obtain films by casting and powders after lyophilisation. Afterwards, lyophilised powders were hot-pressed to obtain films. Hot-pressed films were also prepared from manually mixed SPI/glycerol blends. The films obtained by those three methods were assessed and 30 wt% glycerol was determined as the optimum plasticizer content to improve mechanical properties. Therefore, SPI films plasticized with 30 wt% glycerol were selected in this work for a further analysis of film properties and physicochemical, barrier and optical properties were measured and related to morphological changes and dynamic-mechanical behaviour.

Besides the film properties, the comparison of the environmental impacts caused by the films as a function of the manufacture process used can be a complementary information in order to select the best option [19]. In this context, life cycle assessment (LCA) provides a comprehensive and quantitative analysis of the environmental impacts of products or processes throughout their life cycle [20–22]. Since LCA identifies the activities that cause impacts on the environment, it is a powerful tool to make decisions when developing films. To the best of our knowledge, there is no information related to the environmental impact of film production as a function of the manufacture process employed and, thus, this is the novelty of this work, which is expected to provide relevant data to optimize the processing of SPI films.

## 2. Materials and methods

### 2.1. Materials

Soy protein isolate (SPI), with a minimum of 90% protein content on dry basis, was obtained from ADM Protein Specialties Division, Netherlands. SPI contains a maximum of 5% moisture, 4% fat, 5% ash. Its isoelectric point is 4.6 due to the high content of glutamic acid (Glu, 19.2%) and aspartic acid (Asp, 11.5%). Glycerol, supplied by Panreac, was used as plasticizer.

### 2.2. Film preparation

Two processing methods were analyzed for manufacturing SPI films. On the one hand, the wet (W) process was used, in which SPI film forming dispersions were prepared by mixing 5 g of SPI and 100 mL of distilled water. Dispersions were heated at 80 °C for 30 min under magnetic stirring. Then, 30 wt% glycerol (based on SPI dry basis) was added and dispersions were maintained at 80 °C for other 30 min. Subsequently, dispersions were poured into Petri dishes and dried at room temperature to obtained SPI-W films. On the other hand, the dry (D) process was analyzed. In this case, SPI and glycerol were blended in a Stephan UMC 5 mixer (Stephan, UK) for 5 min at 1500 rpm and the blend was thermally compacted using a caver laboratory press (Neurtek, Spain). The powder was placed between two aluminium plates and it was introduced into the press, previously heated up to 150 °C, and pressed at 12 MPa for 2 min to obtain SPI-D films. All samples were conditioned in an ACS Sunrise 700V bio-chamber (Alava Ingenieros, Spain) at 25 °C and 50% relative humidity for 48 h before testing.

### 2.3. Film characterization

#### 2.3.1. Film thickness

A QuantuMike Mitutoyo hand-held digimatic micrometer (Neurtek, Spain) was used to measure the film thickness to the nearest 0.001 mm. The values obtained for each sample at five different locations were averaged. All the films had values around 80 μm.